Developing a Socioeconomic Vulnerability Index Using two Agricultural Communities Exposed to Climate Change: A Case Study in Wanathawilluwa in Puttlam District of Sri Lanka

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ABSTRACT

The importance of vulnerability and adaptive capacity has been frequently emphasized in explaining the societal aspects of climate change over the last few years. Developments in vulnerability research and consequent adaptation policies, have become a top priority in many countries. With the understanding of the significant importance of agriculture, numerous climate change assessments have been conducted to explore the vulnerability status of agricultural communities, whose livelihood is mostly dependent on natural resources. However, such studies are highly limited in Sri Lanka and the current study was aimed at developing a Socioeconomic Vulnerability Index (SeVI) for two climate change affected agricultural communities in Wanathawilluwa Divisional Secretariat Divisions (DSD) using the concept of “Sustainable Livelihoods Approach” under five specific assets, namely (1) human; (2) social; (3) physical; (4) natural and (5) financial. Fifty households from two Grama-Niladhari Divisions (GN) were surveyed to collect data on three vulnerability dimensions and 17 socioeconomic indicators. The SeVI aggregate was developed as a composite indicator index, where a relative weight was assigned to each indicator with a view of obtaining weighted average index scores. In addition, pentagons were developed for each community by analysing the five assets under 17 indicators. Results suggested that Mangalapura farming community (GN Division) was relatively more vulnerable and most exposed to natural hazards. This study suggests SeVI as a viable approach to assist the policy-makers to identify the most vulnerable communities to climate change and thereby improve the early warning systems. Further, this SeVI can be promoted as a simple but effective tool for comparing socioeconomic vulnerability in hazard prone regions towards climate change.

KEYWORDS: Climate change, Socio-economic vulnerability, Sustainable livelihood approach

Introduction

The changing climate is a threat for both current and future generations, especially due to global warming. According to Intergovernmental Panel on Climate Change (IPCC), climate change is described as a change in the statistical weather patterns for an extended period of time. The two main factors influencing global warming towards climate change are natural internal processes and anthropogenic activities. Extra-terrestrial factors, atmospheric factors, tectonic factors, land and ocean factors are few natural internal processes, while burning of fossil fuels, deforestation are some anthropogenic activities, which could cause changes in the composition of the atmosphere (IPCC, 2013a). The IPCC Fifth Assessment Report has also concluded that human influence has been the dominant cause for climate change, since the mid of twentieth century (IPCC, 2013b).

Climate change leads to a variety of impacts namely fluctuations in temperature, rise in sea level, more frequent droughts and erratic rainfalls. The adverse impacts of climate change mainly influence the environment, agriculture, forest, biodiversity, health, energy and human settlements. Among them, agriculture is considered as one of the most susceptible sectors to climate change, as negative impacts of climate change on crop productivity could challenge the global food security (IPCC, 2013b). Therefore, communities depending on agriculture, as their main livelihood, are facing the consequences of climate change, which directly affects their social and economic conditions. Ultimately, this could lead to various levels of socioeconomic vulnerability. Socio-economic vulnerability of a community is influenced by economic resources, power relationships, institutions or cultural aspects of a social system.

Social vulnerability is a measure of the sensitivity of a population to natural hazards and its ability to respond to and recover from the impacts of hazards (López et al., 2011). It is considered as a precondition that makes an individual or groups of people, more susceptible to harm than others (Reckien, 2018). One of the largest contributors to social vulnerability is social class, which includes employment (type and stability), income, savings, the quality of human settlements (housing type and construction, infrastructure and lifelines), education levels, tenure type, built environment, family structure, population growth, commercial and industrial development, medical services, special needs and nature of the population (Cutter and Emrich, 2006). Socioeconomic vulnerability is vital to determine the direction of influence of a hazardous climate event either as positive or negative. It is also important to evaluate the coping capacity of individuals or households affected by climate hazards. Among several methods of socio-economic vulnerability assessment, (variable reduction approach, variable addition approach and normalization approach) construction of a composite index remains frequently used (Reckien, 2018).

Evidences show that developing countries will face the most adverse effects of climate change, where population are most vulnerable. Further, climate change will affect the potential for development in these countries (Beg et al., 2002). In Sri Lanka, a high degree of vulnerability is expected in Puttlam and Ratnapura districts, due to high exposure, high sensitivity of livelihoods and lower socioeconomic developments.

Puttlam district has 16 Divisional Secretariat Divisions (DSDs) of which, Wanathawilluwa remains as the most vulnerable DSD to floods and droughts. No studies have been conducted to quantify the degree of socio-economic vulnerability and the coping capacity of farming communities to climate change in Wanathawilluwa. Therefore, this research was conducted to develop a SeVI for climate change affected agricultural communities in Wanathawilluwa using a composite indicator framework method.

Methodology

Conceptual Framework

The sustainable Livelihood framework (Figure 1) of International Development (DFID) provides a conceptual framework, which shows how the livelihood assets combine and contribute to different livelihood strategies in order to achieve livelihood outcomes (Ashley and Carney, 1999). This paper proceeds by focusing each component of sustainable livelihood framework.

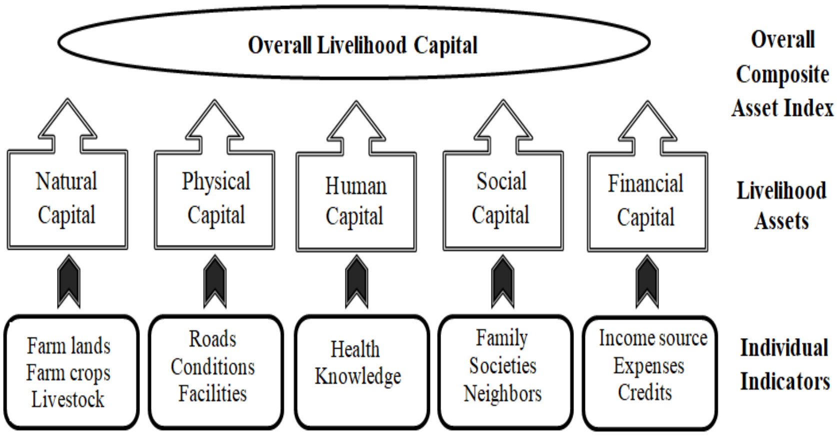

Figure 1. The sustainable livelihood framework (Ashley and Carney, 1999)

Vulnerability to Climate Change

According to Ahsan and Warner (2014), the degree to which a system is susceptible to and unable to cope with adverse effects of climate change, including climate variability and extremes, is known as vulnerability to climate change. IPCC has suggested to characterize the climate change vulnerability through three core concepts: (a) exposure: the nature and degree, to which a system is exposed to significant climatic variations; (b) sensitivity: the degree to which a system is affected, either adversely or beneficially by climate variability and (c) adaptive capacity: the ability of a system to cope or adjust with the negative impacts of a shock. Therefore, vulnerability could be identified as a function of exposure, sensitivity and adaptive capacity (IPCC, 2013a).

Data Collection and Analysis

The study was conducted among two significant agricultural communities of Mangalapura (636/6) and Serakkuliya (635/3) Grama Niladhari Divisions (GND) in Wanathawilluwa. Data were collected through an interviewer based household level survey using a pretested questionnaire incorporated with variety of contributing indicators of vulnerability. Fifty households were randomly selected from each GND. The questionnaire survey was conducted from July to October 2018. Relevant secondary data were also collected to develop the vulnerability index.

The Socioeconomic Vulnerability Index (SeVI)

The SeVI was developed using the Composite Indicator Framework method that has widely used in similar socioeconomic vulnerability studies (Ahsan and Warner, 2014). The following method consists of three main dimensions namely adaptive capacity, sensitivity and exposure. A total of 38 indicators were considered in the development process of the SeVI, which were listed under each dimension based on five assets viz. (1) social, (2) human, (3) financial, (4) physical and (5) natural (DFID, 1999). The selection of the candidate variables was done based on expert opinion and through an extensive literature review. A Principal Component Analysis (PCA) followed by a factor analysis was used to obtain the actual indicators that reflect each domain using SPSS software (Version 23). Accordingly, five assets comprised of 17 indicators were selected as the significant indicators to derive the SeVI.

Since each of the indicators was measured on different scales, it was necessary to standardize each indicator transforming into a unit less index value to obtain an index score of indicator for union "i". The indicators that show a positive relationship were normalized using equation 1, while equation 2 was used to normalize the negative indicators.

$$x_{ij} = \frac{X_{ij} - Min\{X_{ij}\}}{Max\{X_{ij}\} - Min\{X_{ij}\}} \quad [1]$$

$$x_{ij} = \frac{Max\{X_{ij}\} - X_{ij}}{Max\{X_{ij}\} - Min\{X_{ij}\}} \quad [2]$$

Where, x_{ij} is the normalized value and x_i is the actual value of indicator (*j*) with respect to GN (*i*). *Min xj* and *Max xj* are minimum and maximum values respectively to indicator (*j*) among all considering GNDs.

For an indicator this numerical value ranged between zero to one. The maximum and minimum values were usually adjusted to avoid values of more than one. Any remaining values above one or below zero were fixed at one and zero, respectively. After selecting the representative indicators, the sub-indices of vulnerability (exposure, sensitivity and adaptive capacity) were calculated using the equation 3 and equation 4.

$$I_i = \sum[aj \times S_{ij}]\ (i = 1,2,3 \ldots .30) \quad [3]$$

In which, $\sum aj = 1$

Where I_i is the sub-index (exposure, sensitivity or adaptive capacity); *i* remains as the GN of consideration; *aj* is the weight of principle *j* obtained from the component scores and S_{ij} is the value of the principle component *j* of GND *i* calculated as follows:

$$S_{ij} = \sum \beta m \times x_m\ (\beta m > a) \quad [4]$$

Where x_m is the normalized value of indicator *i* and *βm* is the principal component loading of the indicator. Only the indicators with $\beta m > 0.1$ were taken into account as recommended (Abson et al., 2012).

Once the weighted score was obtained for each contributing indicator, Dimension Vulnerability Score was determined by averaging the weighted scores of all indicators within the same dimension. Finally, the socioeconomic vulnerability Index of each GND was obtained by equation 5.

$$\text{SeVI} = \frac{+\text{DI}_{\text{Exposure}} + \text{DI}_{\text{Sensitivity}} - \text{DI}_{\text{Adaptive capacity}}}{3} \quad [5]$$

It was assumed that SeVI possessed a direct relationship with system's exposure and sensitivity and inverse relationship with its adaptive capacity.

Results and Discussion

Exposure Index

Among eight candidate variables namely (1) the average number of droughts in last five years, (2) average number of floods in last five years, (3) average economic impact of droughts on livelihoods, (4) average economic impact of droughts on households, (5) average economic impact of floods on households, (6) average economic impact of floods on households, (7) compensation distributed during droughts and floods and (8) the number of families that have received compensations, only four variables retained in the rotated PCA matrix, remaining as representative indicators for exposure (Table 1).

Table 1. Principal component loadings on indicators of exposure

Indicator	PC1	PC2
Average number of droughts in last five years	0.684	-0.367
Average number of floods in last five years	0.653	-0.673
Average impact of droughts on livelihood	0.321	-0.532
Average impact of floods on households	-0.05	0.360
Weight	**0.726**	**0.274**

Sensitivity Index

A total of nine variables (out of 18 candidate variables) were selected as the potential indicators for sensitivity of the climate change vulnerability of the community. Among those, demographic (percentage of children below 10 years and aged people > 60 years in the sample, number of disabled population in the sample and percentage of kidney patients in the sample), household related (percentage of households without any sanitary latrine facilities, electricity and potential drinking water sources) and economic (percentage of households that depend on agriculture as the main income source and percentage of households without seed stocks) factors could be identified (Table 2).

Table 2. Principal component loadings on indicators of sensitivity

Indicator	PC1	PC2
Percentage of households depend on agriculture as main income source	0.146	-0.043
Percentage of old and children in the sample	-0.037	0.174
Percentage of disabled in the sample	0.120	-0.084
Percentage of kidney patients in the sample	0.106	-0.070
Percentage of households not having sanitary latrine	0.451	0.081
Percentage of households not getting electricity	-0.427	0.106
Percentage of households not having a seed stock	-0.195	0.559
Percentage of households using bulk water for drinking	0.376	-0.109
Weight	**0.824**	**0.176**

Adaptive Capacity Index

For the case of adaptive capacity, only five representative indicators survived the PCA, while another six candidate parameters were removed from the analysis. The retained indicators constituted the adaptive capacity index of the social vulnerability index for agricultural communities in Wanathawilluwa DSD, by reflecting the economic strength (percentage of households with a secondary income source, with access to micro credit facilities and insurance facilities) and the resilience capacity (percentage of household heads who are members of a relevant professional society and with a moderate knowledge on adaptation measures for climate change) of the agricultural communities (Table 3).

Table 3. Principal component loadings on indicators of adaptive capacity

Indicator	PC1	PC2
Percentage of house heads who are members of a society	-0.190	0.117
Percentage of house heads with moderate knowledge on climate change	-0.015	0.379
Percentage of households with a secondary income source	0.437	-0.385
Percentage of households having micro credit facility	0.697	-0.658
Percentage of households having insurance facility	0.536	-0.511
Weight	**0.658**	**0.342**

IPCC-Dimension Wise Vulnerability

Results show that exposure is the most dominant dimension with respect to adaptive capacity and sensitivity. Based on the weighted average scores, Mangalapura (MP) was found (score: 0.31) as the highest vulnerable GND due to natural hazards and Serakkuliya (SK) as the least (score: 0.17). The GND, which showed the highest sensitivity to climate change hazards, was Serakkuliya (score: 0.17), while the community of Mangalapura showed a less sensitivity towards climate change with an average sensitivity score of 0.13. It further indicated that financial, social and physical assets are low in Mangalapura with respect to Serakkuliya (Table 4).

Considering the asset wise social vulnerability, both Mangalapura (score: 0.25) and Serakkuliya (score: 0.25) showed identical results. The weighted average score of human asset in Mangalapura (score: 0.37) was found to be lower than Serakkuliya (score: 0.42). Except the main income source indicator, other indices denoted that the financial assets in adaptive capacity are inversely proportionate to the vulnerability index. Therefore Mangalapura, which had a higher weighted average score for SeVI (0.05) was economically the least vulnerable GND, while Serakkuliya, which had a lower (0.03) average index score was the highest vulnerable. As a whole, the overall socio-economic vulnerability of Mangalapura (score: 0.056) is notably higher than Serakkuliya (score: 0.003).

The livelihood pentagons obtained for both GNDs were not symmetrical in terms of the five assets sustainable Livelihood framework, suggesting that those are not up to the sustainable level. Results showed that exposure was the most dominant dimension compared to sensitivity and adaptive capacity (Figure 2). In Mangalapura, high vulnerability levels of natural and human assets were observed, while physical and human assets were highly vulnerable in Serakkuliya. In both GNDs, financial vulnerability was notably low.

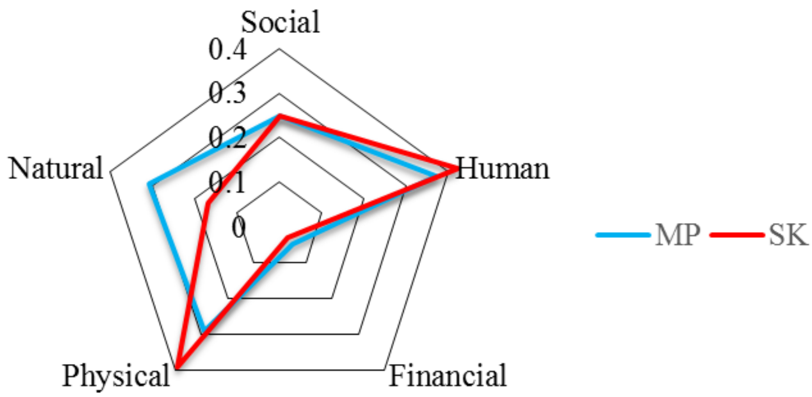

Figure 2. The asset wise livelihood pentagons of two GNDs
MP: Mangalapura and SK: Serakkuliya

Table 4. Indicator index scores and overall SeVI scores for Mangalapura (MP) and Serakkuliya (SK) GNDs of Wanathawilluwa, Puttlam District

IPCC Dimensions	Asset Type	Indicators	MP	SK
Exposure	N	Average number of droughts in last five years	5.12	3.16
	N	Average number of floods in last five years	2.8	1.1
	N	Average impact of droughts on livelihood	4.78	3.8
	N	Average impact of floods on households	1.34	1.14
	Weighted average score		**0.31**	**0.17**
Sensitivity	F	Percentage of households depend on agriculture as main income source	54	62
	S	Percentage of old and children in the sample	43.38	30.43
	S	Percentage of disabled in the sample	1.05	1.44
	S	Percentage of kidney patients in the sample	5.82	0.48
	P	Percentage of households not having sanitary latrine	38	0
	P	Percentage of households not getting electricity	34	0
	P	Percentage of households not having a seed stock	96	28
	P	Percentage of households using bulk water for drinking	22	94
	Weighted average score		**0.13**	**0.17**
Adaptive Capacity	S	Percentage of house heads who are members of a society	76	68
	H	Percentage of house heads with moderate knowledge on climate change	56	62
	F	Percentage of households with a secondary income source	72	94
	F	Percentage of households having micro credit facility	62	54
	F	Percentage of households having insurance facility	20	36
	Weighted average score		**0.27**	**0.33**
Overall SeVI score			**0.056**	**0.003**

Note: N- Natural, F-Financial, S-Social, P-Physical, H-Human Assets, SeVI-Socio-economic Vulnerability Index

Therefore, relevant entities should focus on strengthening the physical, natural and human assets in the study areas to improve climate resilience. A similar study conducted by Ahsan and Warner (2014) to evaluate the SeVI of south-western coastal area of Bangladesh, has evidenced that only exposure and sensitivity are more dominant than adaptive capacity. In contrast, only the exposure variable was found to be dominant in this study.

Conclusions

In this study, the vulnerability status of two agricultural communities has been explored and assessed using longitudinal analysis on farming households' response towards climate change impacts. The objectives of this study were to develop an index (SeVI) that measures socioeconomic vulnerability of two GNDs in Wanathawilluwa and to assess the relative magnitude of vulnerability of both in asset wise and IPCC dimensions wise. As suggested by the results, the overall socio-economic vulnerability of Mangalapura was significantly higher than Serakkuliya. Due to the impact of floods and droughts in Wanathawilluwa, the economic opportunities for the people have become very limited. Hence, they could hardly secure their daily livelihood. This fact was very clearly reflected from this study through SeVI. Furthermore, the results of this study showed that the newly developed SeVI is a simple but promising approach to capture the vulnerability scenario of agricultural communities to climate change.

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